DRAFT
Parkers River Embayment System
Total Maximum Daily Loads
For Total Nitrogen
(CN 335.0)

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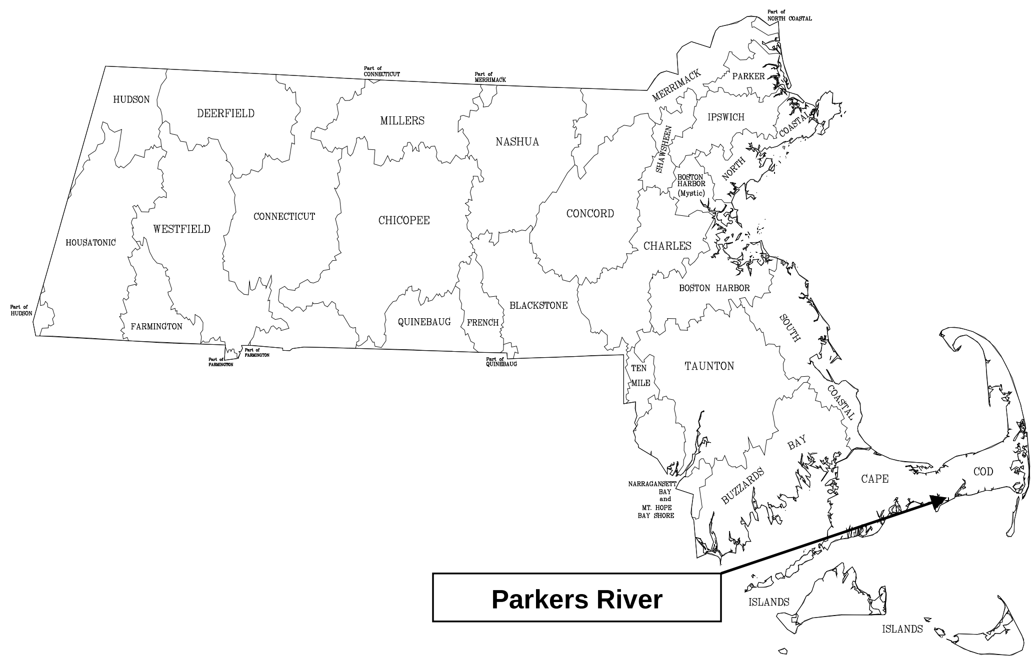

Key Feature:	Total Nitrogen TMDL for Parkers River Embayment System
Location:	US Environmental Protection Agency (EPA) Region 1, Yarmouth, MA
Land Type:	New England Coastal
303d Listing:	Parkers River (Segment MA96-38) is on the Category 4a list 2014 MA Integrated List of Waters with a completed TMDL for fecal coliform. Parkers River, Seine Pond (Segment MA96-110_2018), and Lewis Pond (Segment MA96-109_2018) were found to be impaired for nutrients during the MEP study and will be listed in a future List of Waters as impaired.
Data Sources:	University of Massachusetts – Dartmouth/School for Marine Science and Technology; US Geological Survey; Applied Coastal Research and Engineering, Inc.; Cape Cod Commission; Town of Yarmouth
Data Mechanism:	Massachusetts Surface Water Quality Standards, Ambient Data, and Linked Watershed Model
Monitoring Plan:	Town of Yarmouth monitoring program with assistance from SMAST
Control Measures:	Sewering, hydrodynamic modifications to Rt. 28 culvert, and implementation of best management practices for the control of non-point sources.

Executive Summary

Problem Statement

Excessive nitrogen (N) originating from a wide range of sources has added to the impairment of the environmental quality of the Parkers River Embayment System. In the Parkers River estuary, the most significant impairments are the loss of eelgrass in the lower Parkers River basin and impaired benthic infauna in Seine Pond. In general, excessive N in these waters is indicated by:

- Undesirable increases in macroalgae;
- Periodic extreme decreases in dissolved oxygen concentrations that threaten aquatic life;
- Reductions in the diversity of benthic animal populations;
- Significant loss of eelgrass habitat;
- Periodic algae blooms.

With proper management of nitrogen inputs, these trends can be reversed. Without proper management more severe problems might develop, including:

- Periodic fish kills;
- Unpleasant odors and scum;
- Benthic communities reduced to the most stress-tolerant species, or in the worst cases, near loss of the benthic animal communities.

Coastal communities rely on clean, productive and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing and boating, as well as for commercial fin fishing and shellfishing. Failure to reduce and control N loadings could result in an overabundance of macroalgae, a higher frequency of extreme decreases in dissolved oxygen concentrations and fish kills, widespread occurrence of unpleasant odors and visible scum, and a complete loss of benthic macroinvertebrates throughout most of the embayments. As a result of these environmental impacts, commercial and recreational uses of the Parkers River estuarine system will be greatly reduced.

Sources of Nitrogen

Nitrogen enters the waters of coastal embayments from the following sources:

- The watershed
    - Natural background
    - Septic systems
    - Runoff
    - Fertilizers
    - Agricultural activities
    - Landfills
    - Wastewater treatment facilities;
- Atmospheric deposition
- Nutrient-rich bottom sediments in the embayments

Figure ES-1 illustrates the percent contribution of all the sources of N ("overall load") and the controllable N sources to the estuary system ("local control load"). Values are from Table IV-3 and Figure IV-5 from the Massachusetts Estuaries Project (MEP) Parkers River Embayment

System Technical Report (Howes *et. al*, 2010). As evident, most of the present overall load and most of the controllable load of nitrogen to this system comes from wastewater (septic systems).

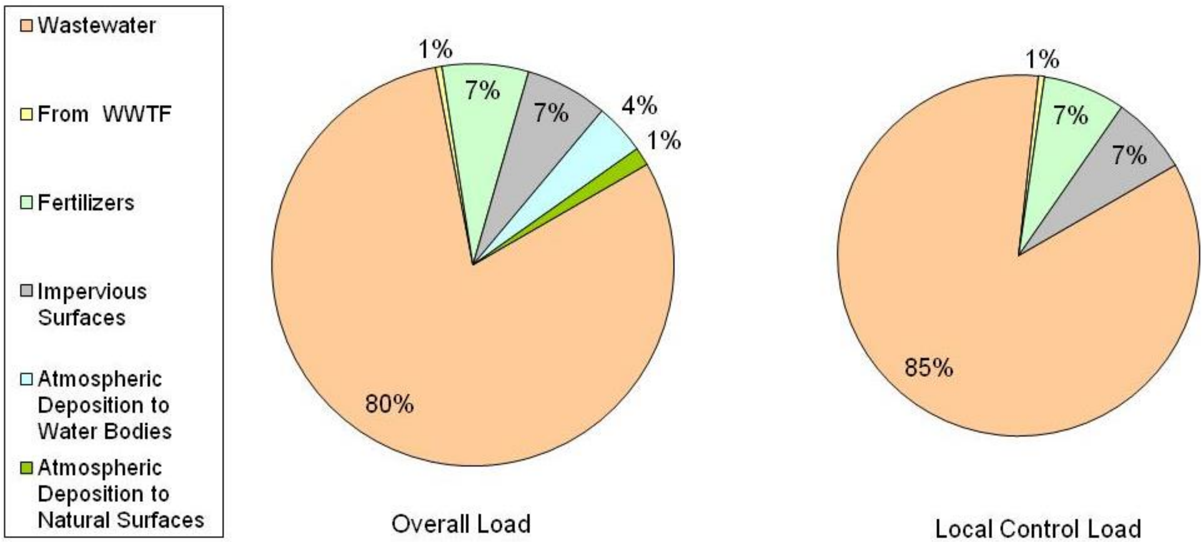

Figure ES-1- Relative Contribution of All Nitrogen Sources (Uncontrollable and Controllable) in the Parkers River Embayment System

Target Threshold Nitrogen Concentrations and Loadings

The Parkers River estuary lies entirely within the Town of Yarmouth on Cape Cod, Massachusetts. The total attenuated watershed N loading (the quantity of N) to the system is approximately 67 kg N/day. The overall total nitrogen load to the embayment system including direct atmospheric deposition of nitrogen to the embayment surfaces and the net benthic flux of nitrogen from the sediments is approximately 98 kg N/day. Current water column concentrations of N in the embayment system ranged from 0.663-0.994 mg/L throughout the entire system (range of annual means collected from 5 stations during 2002-2008 as reported in Table VI-1 of the MEP Parkers River Embayment System Technical Report, Howes *et. al*, 2010 and Appendix A).

In order to restore and protect this estuarine system, N loadings and subsequently, the concentrations of N in the water must be reduced to levels below those that cause the observed environmental impacts. This N concentration will be referred to as the target threshold N concentration. The Massachusetts Estuaries Project (MEP) has determined that by achieving a total N concentration of 0.42 mg/L at the sentinel station located between stations PR-2 and PR-3 in the lower reach of the Parkers River, located at the uppermost extent of the historical eelgrass coverage, water and habitat quality will be restored in this system (see Figures 6 and 7). The mechanism for achieving the target threshold N concentration is to reduce the N loadings to the watershed of the estuarine system.

Based on the MEP sampling and modeling analyses (Howes *et. al*., 2010), the Massachusetts Department of Environmental Protection (MassDEP) has adopted a range of Total Maximum

Daily Loads (TMDLs) of N throughout the embayment system. The values of the TMDLs range from 5.18 to 18.02 kg/day for the different subembayments with a total Parkers River Embayment System TMDL of 35.47 kg N/day. (Note: this number is slightly different from the technical report as negative benthic flux was set to zero in the TMDL.). For the Parkers River Embayment System an overall approximately 80% reduction in watershed N loads is required to meet target threshold N concentrations and restore this embayment system.

This document presents the TMDLs for the Parkers River estuarine system and suggests possible options to Yarmouth on how to reduce the N loadings to meet the recommended TMDLs and protect the waters of this embayment system.

Implementation

The primary goal of implementation will be to lower the concentrations of N by greatly reducing the loadings from on-site subsurface wastewater disposal systems through a variety of centralized or decentralized methods such as sewering and treatment with nitrogen removal technology, advanced treatment of septage, and/or installation of N-reducing on-site systems. There may be other loading reduction scenarios that could achieve the target threshold N concentrations than were explored in the MEP Technical Report. These options would require additional modeling to verify their effectiveness.

These strategies, plus ways to reduce N loadings from stormwater runoff and fertilizers, are explained in detail in *The Massachusetts Estuaries Project: Embayment Restoration and Guidance for Implementation Strategies* (MassDEP 2003). The appropriateness of any of the alternatives will depend on local conditions, and will have to be determined on a case-by-case basis, using an adaptive management approach. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under the Clean Water Act Section 208.

Finally, growth within the community of Yarmouth that would exacerbate the problems associated with N loadings, should be guided by considerations of water quality-associated impacts.

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Introduction

Section 303(d) of the Federal Clean Water Act requires each state to identify waters not meeting their intended uses (based on water quality standards), and to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. The TMDL allocation establishes the maximum loadings (of pollutants of concern), from all contributing sources, that a water body may receive and still meet and maintain its water quality standards and designated uses, including compliance with numeric and narrative standards. The TMDL development process may be described in four steps, as follows:

1. Determination and documentation of whether or not a water body is presently meeting its water quality standards and designated uses.

2. Assessment of present water quality conditions in the water body, including estimation of present loadings of pollutants of concern from both point sources (discernable, confined, and concrete sources such as pipes) and non-point sources (diffuse sources that carry pollutants to surface waters through runoff or groundwater).

3. Determination of the loading capacity of the water body. EPA regulations define the loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. If the water body is not presently meeting its designated uses, then the loading capacity will represent a reduction relative to present loadings.

4. Specification of load allocations, based on the loading capacity determination, for non-point sources and point sources that will ensure that the water body will not violate water quality standards.

After public comment and final approval by the EPA, the TMDLs will serve as a guide for future implementation activities. The MassDEP will work with the municipalities to develop specific implementation strategies to reduce N loadings, and will assist in developing a monitoring plan for assessing the success of the nutrient reduction strategies.

In the Parkers River Embayment System, the pollutant of concern for this TMDL (based on observations of eutrophication) is nitrogen (N). Nitrogen is the limiting nutrient in coastal and marine waters, which means that as its concentration is increased, so is the amount of plant matter. This leads to nuisance populations of macroalgae and increased concentrations of phytoplankton and epiphyton that imperil the healthy ecology of the affected water bodies.

The TMDL for total N for the Parkers River Embayment System is based primarily on data collected, compiled, and analyzed by University of Massachusetts Dartmouth's School of Marine Science and Technology (SMAST) and the Town of Yarmouth, as part of the Massachusetts Estuaries Project (MEP). The data were collected over a study period from 2002 through 2008. This study period will be referred to as the "present conditions" in the TMDL since it contains the most recent data available. The MEP Technical Report for this embayment system can be found at http://www.oceanscience.net/estuaries/ParkersRiver.htm.

or at http://www.mass.gov/eea/agencies/massdep/water/watersheds/the-massachusetts-estuaries-project-and-reports.html.

The MEP Technical Report presents the results of the analyses of the coastal embayment system using the MEP Linked Watershed-Embayment Nitrogen Management Model (Linked Model) (Howes *et. al*, 2010)

The analyses that were performed can assist Yarmouth in making decisions on current and future wastewater planning, wetland restoration, anadromous fish runs, shellfisheries, open space, and waterways maintenance programs. Critical elements of this approach are the assessment of water quality monitoring data, time-series water column oxygen and chlorophyll measurements, and benthic community structure analyses that were conducted on this embayment. These assessments served as the basis for generating a nitrogen loading threshold for use as a goal for watershed nitrogen management. The TMDLs are based on the site-specific nitrogen threshold generated for this embayment system. Thus, the MEP offers a science-based management approach to support the town of Yarmouth's wastewater management planning and decision-making process.

Description of Water Bodies and Priority Ranking

Watershed Characterization

The Parkers River embayment system watershed is located entirely within the town of Yarmouth. The MEP team, including technical staff from the United States Geological Survey (USGS), using sophisticated groundwater models has delineated a Parkers River embayment system watershed area of approximately 5.4 square miles. The delineated contributory watershed includes twenty subwatersheds, including three subwatersheds named Long Pond well, Long Pond and Long Pond stream whose groundwater contribution depends on well pumping and streamflow (Figure 1, Howes *et. al*, 2010, pg. 28).

The MEP project has assessed landuse in the Parkers River embayment system using Town of Yarmouth assessor's data. Landuse was summarized into eight categories including residential, commercial, industrial, mixed use, undeveloped, agricultural, public service/government (including rights of way) and freshwater features. The landuse summary follows Massachusetts Department of Revenue classifications (MassDOR 2008) and the public service category signifies tax exempt properties including land owned by government and private non-profits. The most common landuse categories are public service and residential which compromised 49% and 40% of the overall Parkers River watershed respectively (Howes *et. al*, pg. 33). The watershed is close to its full buildout with only 2% of the overall watershed area considered undeveloped.

Description of Waterbodies

The Parkers River embayment system consists of two salt ponds (Seine Pond and Lewis Pond) and a tidal river, the Parkers River, which connects to Nantucket Sound. The inlet to the embayment system was channelized and armored with jetties in the early 20th century. Currently the inlet is maintained through periodic dredging by the Town of Yarmouth. The MEP project has divided the Parkers River embayment system into four distinct areas for analysis: Lewis Pond, Lower Parkers River (below Rte. 28), Upper Parkers River (above Rte. 28) and Seine Pond (Figure 2).

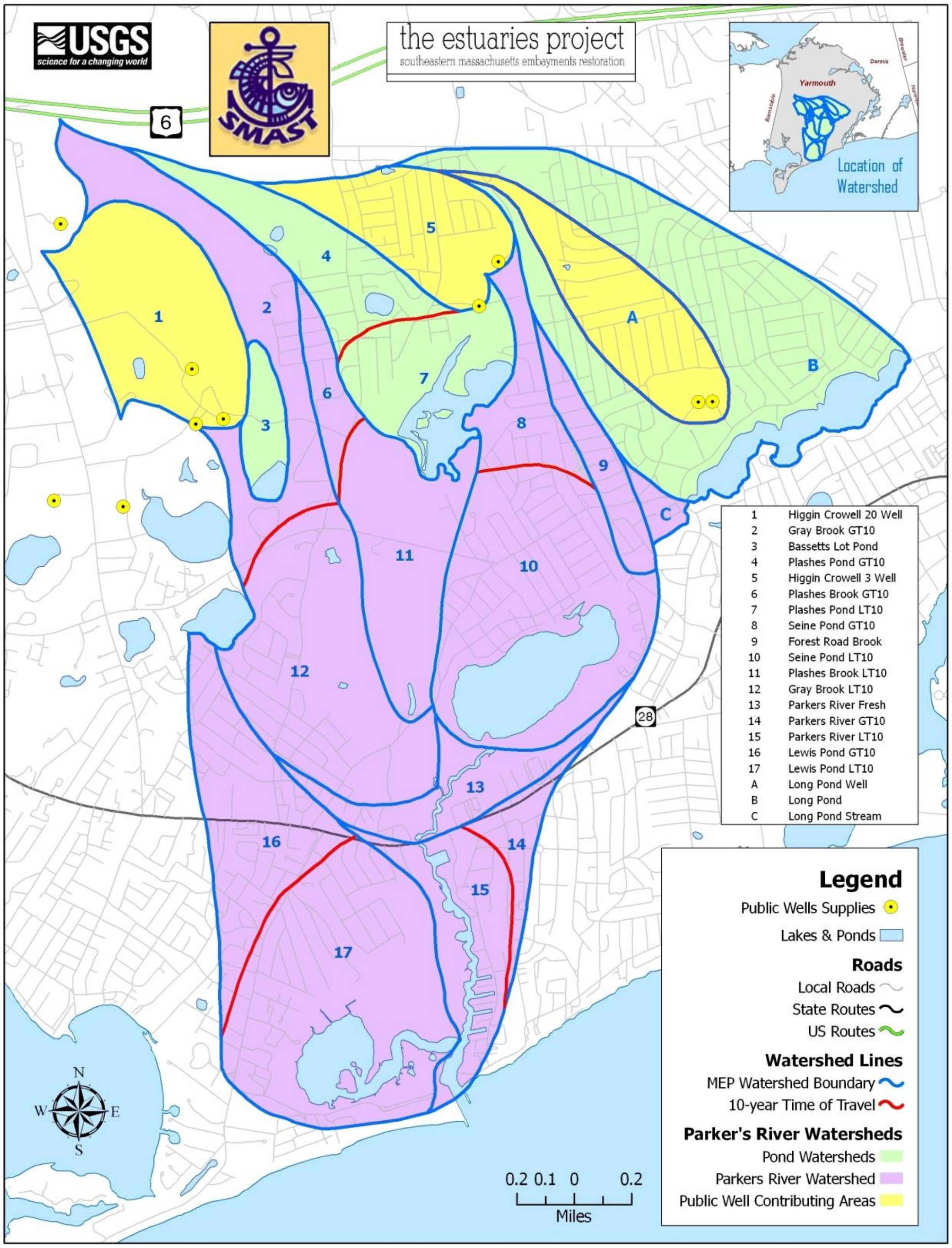

Figure 1: MEP Watershed Delineation for the Parkers River Embayment System (Howes *et. al*, 2010)

Figure 2: Overview of the Parkers River Embayment System in Yarmouth, MA.

The Parkers River which includes the Lower Parkers River and the Upper Parkers River is listed in the Massachusetts Year 2014 Integrated List of Waters (MassDEP 2016) in Category 4a Waters – "TMDL is completed" for fecal coliform, non attainment of the shellfish use (MassDEP, US EPA and ENSR International 2009). Lewis Pond and Seine Pond described in this report had not been assessed (Table 1). Though not listed in the Massachusetts Year 2014 Integrated List of Waters for nitrogen, this embayment system (Seine Pond to mouth at Nantucket Sound) was found to be impaired for elevated total nitrogen, low dissolved oxygen levels, elevated chlorophyll-*a* levels, loss of eelgrass, and degraded benthic infauna habitat during the MEP technical study. These segments will be listed as impaired for nutrients in a future MA Integrated List of Waters.

The Parkers River Embayment System is at risk of further eutrophication from high nutrient loads in the groundwater and runoff from their watersheds. Please note that pathogens are listed in Table 1 for completeness. Further discussion of pathogens or other habitat alterations is beyond the scope of this TMDL.

Priority Ranking

Restoration of the coastal resources in Massachusetts is an important priority. The Parkers River embayment system specifically is a high priority based on three significant factors: (1) the initiative that the Town of Yarmouth has taken to assess the conditions of the entire embayment system, (2) the commitment made by the Town to restore and preserve the embayment, and (3) the need to halt further degradation to prevent the existing impairments from becoming further worsening. In particular, portions of the Parkers River system are at risk of further degradation from increased N loads entering through groundwater and surface water from their increasingly developed watersheds. In both marine and freshwater systems, an excess of nutrients results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources.

Table 1: Parkers River Embayment System Waterbodies and 303d Integrated List Category

Waterbody Name	MassDEP Segment Number	MassDEP Segment Description	Class	2014 Integrated List Category	SMAST Impaired Parameter[1]	Size (acres)[1]
Seine Pond	MA96-110_2018	East of Winslow Gray Road, Yarmouth	SA	Not assessed	TN, DO, Chloro- *a*, Macroalgae, Benthic Infauna	89.3
Upper Parkers River	MA96-38_2012	Parkers River (Outlet Seine Pond, Yarmouth to mouth at Nantucket Sound, Yarmouth.)	SA	4A[3] Fecal coliform TMDL completed for nonattainment of shellfish use	TN, DO, Chloro-*a*, Benthic Infauna	4.1
Lower Parkers River	MA96-38_2012	Parkers River (Outlet Seine Pond, Yarmouth to mouth at Nantucket Sound, Yarmouth.)	SA	4A[3] Fecal coliform TMDL completed for nonattainment of shellfish use	TN, DO, Chloro-*a*, Macroalgae, Eelgrass loss, Benthic Infauna	21.7
Lewis Pond	MA96-109_2018	North of Seagull Road, Yarmouth (includes tidal channel to Parkers River)	SA	Not assessed	TN, DO[2], Chloro-*a*, Benthic Infauna	50.2

1- As calculated/determined during MEP project
2- Principally a salt marsh pond, dissolved oxygen levels may be result of natural organic enrichment although high observed Chlorophyll *a* indicated impairment due to nitrogen loads also likely a factor
3- Category 4A – TMDL is completed, EPA #36771

Description of Hydrodynamics of Embayment System

The MEP project has evaluated the tidal circulation and flushing characteristics of this embayment system using both direct measurements and the RMA-2 model, a well established model for estuaries. Using direct measurement of the tides at four locations in the embayment system, Howes *et. al* (2010) determined that the Rte 28 culvert causes tidal dampening and a phase delay of a main tidal constituent (lunar, twice per day tide, or M2). An approximately 90 minute delay in this main tidal constituent was found between north of the Rte. 28 bridge and south of the bridge. Ultimately the tidal constriction at the Rte 28 culvert limits the volume of water which reaches Seine Pond and limits flushing.

Problem Assessment

Coastal watersheds have seen large increases in population throughout the country. Nutrient loading to coastal embayments has been associated with increases in population. Due to increased population and nutrient loadings many embayments are showing the symptoms of coastal eutrophication which may include reductions in eelgrass biomass, a shift towards a phytoplankton dominated algal community, increased ecosystem metabolism, shifts in benthic infauna, changes in dissolved oxygen dynamics as well as other unhealthy conditions for aquatic life. The loss of eelgrass is of particular concern in coastal embayments since eelgrass habitat serves as a nursery for many fish.

Coastal communities, including Yarmouth, rely on clean, productive and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing and boating, as well as commercial fin fishing and shell fishing. The continued degradation of this coastal embayment, will significantly reduce the recreational and commercial value and use of these important environmental resources.

Figure 3 shows how the population of Yarmouth has grown from around 3,300 people in 1950 to approximately 23,800 people in 2010. Since 1950 the Town of Yarmouth has seen a compound annual growth rate in the resident population of 3.35%. The resident population growth rate since 1900 for Yarmouth is slightly slower with a compound annual growth rate of approximately 2.4%. The summer population on Cape Cod is estimated to be two to three times year round residential population (Howes *et. al*, 2010). Increases in N loading to estuaries are directly related to increasing development and population in the watershed. Yarmouth's population has increased six fold in the past 60 years and an increase in population contributes to a decrease in forests and increases in septic systems, runoff from impervious surfaces and fertilizer use.

The Parkers River Embayment consists of Seine Pond, Lewis Pond and the Parkers River (Figure 2). MEP analysis has found that greater than 90% of the embayment system is showing significant to moderate habitat impairments (Howes *et. al*, 2010, pg ES-6). The severity of nitrogen related impairment follows a gradient with residence time. Seine Pond, a salt pond, is impaired due to poor benthic fauna, phytoplankton blooms, low dissolved oxygen and macroalgal accumulations (Howes *et. al* 2010, pg. ES-5).

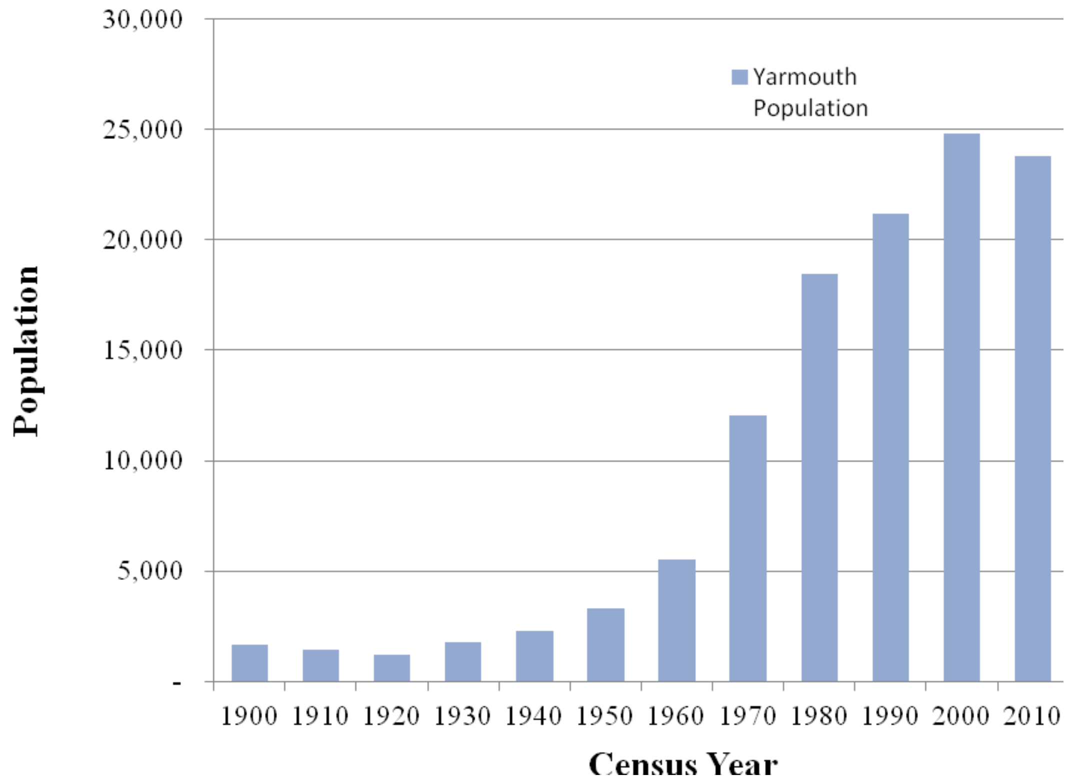

Figure 3: Resident Population for the Town of Yarmouth, MA

The Parkers River has seen a complete loss of eelgrass beds and shows moderate to significant impairment due to high chlorophyll-*a* levels and periodic dissolved oxygen depletion. Lewis Pond, a salt marsh pond, shows nutrient related impacts in high chlorophyll-*a* levels and a benthic infauna dominated by opportunistic species indicative of organic matter overloading.

Lewis Pond has the lowest baseline dissolved oxygen concentrations in the embayment system and shows dissolved oxygen stress which can be partly evaluated through the prism of salt marsh tidal basins which are naturally, organic matter enriched and often have periodic hypoxia. The oxygen depletion and moderate to high chlorophyll- *a* levels documented in the Parkers River are likely due to the river's role "transporting high nutrient, high phytoplankton, low oxygen waters from Seine and Lewis Ponds to Nantucket Sound on the ebb tide" (Howes *et. al*, 2010 pg. 120).

The MEP has developed a threshold classification system which relates ecological health and habitat quality along a nitrogen gradient (Howes *et. al* 2003). An assessment of nutrient related habitat quality for the Parkers River Embayment system is summarized in Table 2. Howes *et. al* (2010) have detailed a complete accounting of nutrient related impacts and the ecological health of the Parkers River embayment system.

Table 2: Parkers River Embayment System MEP Nutrient Related Habitat Quality Determination (from Table VIII-1, Howes *et. al* 2010)

Parkers River Embayment System	Eelgrass Loss	Dissolved Oxygen Depletion	Chlorophyll *a*	Benthic Fauna[1]	Macroalgae	Overall Heath
Seine Pond	NA	oxygen depletions frequently <6 mg/L, infrequently to <4 mg/L, minimum=3.4 mg/L; YWQMP[2] minimum D.O. (2002-08) = 3.6 mg/L & 1.9 mg/L at "deep" site **[MI-SI]**	very high chlorophyll, average 2004 = 26ug/L, 2002-08 = 12-15ug/L, frequent blooms to >40ug/L **[SD]**	low numbers of species & individuals, low diversity & Evenness, dominated by organic enrichment and stress tolerant opportunistic species **[SI-SD]**	dense patches of drift algae, Ulva, with some filamentous species mostly in basin's lower half **[SI]**	Significant Impairment based primarily on the high sustained chlorophyll levels, periodic oxygen depletions and the depaupate benthic community dominated by stress indicator species **[SI]**
Upper Parkers River	NA	oxygen levels dominated by ebbing Seine Pond waters, minimum =3.6 mg/L (YWQMP, 2002-08) **[MI-SI]**	moderate to high summer chlorophyll levels averaging 8 ug/L (YWQMP, 2002-2008) **[SI]**	assessment based upon mouth of Seine Pond samples showing low diversity, Evenness, low total numbers of species and individuals, the upper River is presently dominated by Seine Pond outflow **[MI-SI]**	NA	Moderate to Significant Impairment, primarily due to sustained high chlorophyll levels & periodic D.O. depletion. Dominated by outflows of low D.O., high organic matter waters from Seine Pond. **[MI-SD]**
Lower Parkers River	complete loss of eelgrass from this system between 1951-1995 **[SI]**	oxygen levels periodically depleted, water quality monitoring minimum (2002-08)=4.4 mg/L **[MI]**	low to moderate summer chlorophyll levels averaging 4 ug/L (YWQMP, 2002-2008) **[MI]**	high numbers of species and high number of individuals, dense amphipod mats indicative of disturbance and/or moderate levels of organic enrichment. **[MI]**	patches of drift algae, Ulva, with some filamentous species and some algal mat **[MI]**	Significant Impairment based upon loss of eelgrass from system, 1951-1995 **[SI]**

Table 2 (continued): Parkers River Embayment System MEP Nutrient Related Habitat Quality Determination (from Table VIII-1, Howes *et. al* 2010)

Parkers River Embayment System	Eelgrass Loss	Dissolved Oxygen Depletion	Chlorophyll *a*	Benthic Fauna[1]	Macroalgae	Overall Heath
Lewis Pond	NA	primarily a salt marsh pond, frequent oxygen depletion to <4 mg/L, periodically to 3 mg/L; basin surrounded by extensive tidal saltmarsh resulting in natural organic enrichment **[H-MI]**	high chlorophyll levels, YWQMP average 2002-08 = 9 ug/L **[MI]**	moderate numbers of individuals, high/moderate species, high diversity and Evenness; some organic enrichment indicators typical of salt marsh ponds and some deep burrowers, but dominated by opportunistic species indicative of organic matter overloading. **[H-MI]**	drift algae sparse or absent, small patches of Ruppia (common to salt marsh ponds) **[H]**	Moderate Impairment based upon the elevated chlorophyll and infaunal community structure, particularly the dominance by tubificids **[MI]**

NA= not applicable to this estuarine reach, H= healthy, MI = moderate impairment,
SI= significant impairment, SD= severe degradation (These terms are more fully described in Howes *et. al* 2003)
[1] Based on observations of the types of species, number of species, and number of individuals.
[2] YWQMP = Yarmouth Water Quality Monitoring Program, data collected 2002-2008.

Pollutant of Concern, Sources and Controllability

In the Parkers River Embayment System, as in most marine and coastal waters, the limiting nutrient is nitrogen (N). Nitrogen concentrations above those expected naturally contribute to undesirable water quality and habitat conditions through the promotion of excessive growth of plants, algae and nuisance vegetation.

Extensive data was collected and analyzed through the MEP, with the cooperation and assistance from the Town of Yarmouth. These investigations revealed that loadings of nutrients, especially N, are much larger than they would be under natural conditions and, as a result, the water quality has deteriorated. Figure 4 illustrates the sources and their percent contributions of N into the Parkers River Embayment System. As evident, most (80%) of the N entering this system originates from on-site subsurface waste water disposal systems (septic systems).

The level of "controllability" of each source, however, varies widely. A brief overview of the sources of nitrogen and their contributions are detailed in Table 3. Cost/benefit analyses will have to be conducted for all possible N loading reduction methodologies in order to select the optimal control strategies, priorities, and schedules.

Description of the Applicable Water Quality Standards

The waterbodies that make up the Parker River Embayment System are all classified as Class SA waterbodies in the Massachusetts Water Quality Standards (MassDEP 2007). Massachusetts currently has narrative standards for nutrients (nitrogen and phosphorus) for waters of the Commonwealth such that "all surface waters shall be free of nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed site specific criteria developed in a TMDL or otherwise, established by the department" (MassDEP 2007). A more through explanation of applicable standards can be found in Appendix B.

Thus, the assessment of eutrophication is based on site-specific information within a general framework that emphasizes impairment of uses and preservation of a balanced indigenous flora and fauna. This approach is recommended by the US Environmental Protection Agency in their Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters (EPA-2001). The guidance manual notes that lakes, reservoirs, streams, and rivers may be subdivided by classes, allowing reference conditions for each class and facilitating cost-effective criteria development for nutrient management. However, individual estuarine and coastal marine waters tend to have unique characteristics, and development of individual water body criteria is typically required.

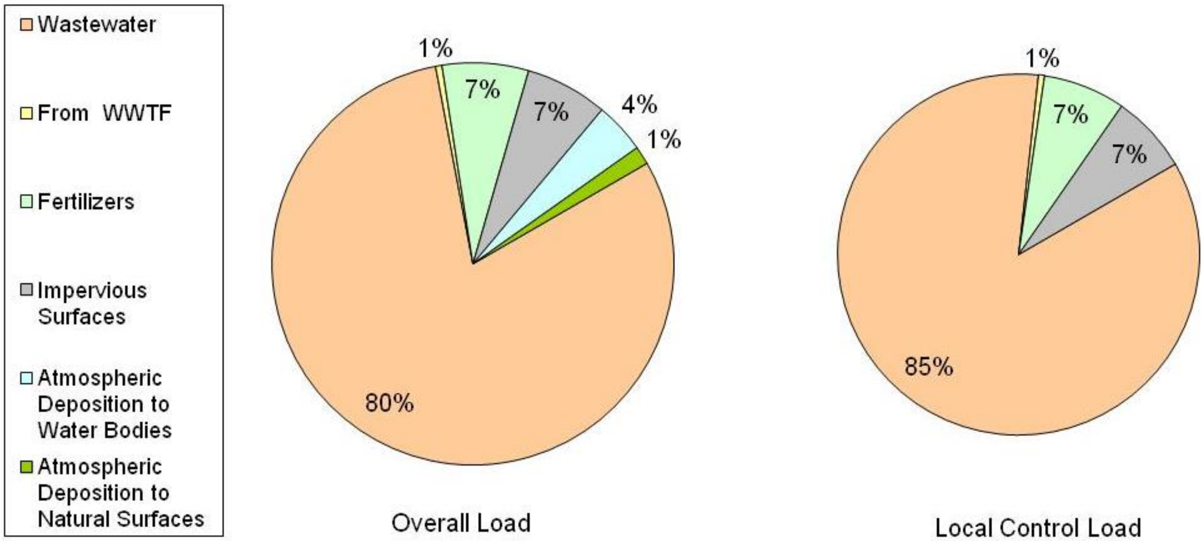

Figure 4: Relative Contribution of All Nitrogen Sources (Overall Load Includes Uncontrollable and Controllable) in the Parkers River Embayment System. (Howes *et. al*, 2010)

(report continued next page)

Table 3: Sources of Nitrogen and their Controllability

Nitrogen Source	Degree of Controllability at Local Level	Reasoning
Agricultural fertilizer and animal wastes	Moderate	These nitrogen loadings can be controlled through appropriate agricultural Best Management Practices (BMPs).
Atmospheric deposition to the estuary surface	Low	It is only through region- and nation-wide air pollution control initiatives that significant reductions are feasible. Local control although helpful is not adequate.
Atmospheric deposition to natural surfaces (forests, fields, freshwater bodies) in the watershed	Low	Atmospheric deposition (loadings) to these areas cannot adequately be controlled locally. However, the N from these sources might be subjected to enhanced natural attenuation as it moves toward the estuary.
Fertilizer	Moderate	Lawn and golf course fertilizer and related N loadings can be reduced through BMPs, bylaws and public education.
Septic system	High	Sources of N can be controlled by a variety of case-specific methods including: sewering and treatment at centralized or decentralized locations, transporting and treating septage at treatment facilities with N removal technology either in or out of the watershed, or installing N-reducing on-site wastewater treatment systems.
Sediment	Low	N loadings are not feasibly controlled on a large scale by such measures as dredging. However, the concentrations of N in sediments, and thus the loadings from the sediments, will decline over time if sources in the watershed are removed, or reduced to the target levels discussed later in this document. In addition, increased dissolved oxygen will help keep N from fluxing.
Stormwater runoff from impervious surfaces	Moderate	This nitrogen source can be controlled by BMPs, bylaws and stormwater infrastructure improvements and public education. Stormwater NPDES permit requirements help control stormwater related N loadings in designated communities.
Wastewater treatment facility (WWTF)	High	Wastewater treatment facilities as point sources of pollution to surface water are permitted under the National Pollution Discharge Elimination System. Treated wastewater effluent discharged to groundwater disposal systems are permitted by MassDEP. There is a high degree of regulatory certainty that within the limits of technology, nutrient sources at these facilities can be controlled.

Methodology - Linking Water Quality and Pollutant Sources

Extensive data collection and analyses have been described in detail in the MEP Technical Report. Those data were used by SMAST to assess the loading capacity of each embayment. Physical (Chapter V), chemical and biological (Chapters IV, VII, and VIII) data were collected and evaluated. The primary water quality objective was represented by conditions that:

1) Restore the natural distribution of eelgrass because it provides valuable habitat for shellfish and finfish;
2) Prevent harmful or excessive algal blooms;
3) Restore and preserve benthic communities;
4) Maintain dissolved oxygen concentrations that are protective of the estuarine communities.

The details of the data collection, modeling and evaluation are presented and discussed in Chapters IV, V, VI, VII and VIII of the MEP Technical Report. The main aspects of the data evaluation and modeling approach are summarized below.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach. It fully links watershed inputs with embayment circulation and N characteristics, and is characterized as follows:

- Requires site specific measurements within the watershed and each sub-embayment;
- Uses realistic "best-estimates" of N loads from each land-use (as opposed to loads with built-in "safety factors" like Title 5 design loads);
- Spatially distributes the watershed N loading to the embayment;
- Accounts for N attenuation during transport to the embayment;
- Includes a 2D or 3D embayment circulation model depending on embayment structure;
- Accounts for basin structure, tidal variations, and dispersion within the embayment;
- Includes N regenerated within the embayment;
- Is validated by both independent hydrodynamic, N concentration, and ecological data;
- Is calibrated and validated with field data prior to generation of "what if" scenarios.

The Linked Model has been applied previously to watershed N management in over 50 embayments thus far throughout Southeastern Massachusetts. In these applications it became clear that the model can be calibrated and validated and has use as a management tool for evaluating watershed N management options.

The Linked Model, when properly calibrated and validated for a given embayment becomes a N management-planning tool as described in the model overview below. The model can assess solutions for the protection or restoration of nutrient-related water quality and allows testing of management scenarios to support cost/benefit evaluations. In addition, once a model is fully functional it can be refined for changes in land-use or embayment characteristics at minimal cost. Since the Linked Model uses a holistic approach that incorporates the entire watershed, embayment and tidal source waters, it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries. It should be noted that this approach includes high-order, watershed and sub-watershed scale modeling necessary to develop critical nitrogen targets for each major sub-embayment. The models, data and assumptions used in this process are specifically intended for the purposes stated in the MEP Technical Report, upon which this TMDL is based. As such, the Linked Model process does not contain the type of data or level and scale of analysis necessary to predict the fate and transport of nitrogen through groundwater from specific sources. In addition, any determinations related to direct and immediate hydrologic connection to surface waters are beyond the scope of the MEP's Linked Model process.

The Linked Model provides a quantitative approach for determining an embayment's (1) N sensitivity, (2) N threshold loading levels (TMDL) and (3) response to changes in loading rate. The approach is fully field validated and unlike many approaches, accounts for nutrient sources, attenuation and recycling and variations in tidal hydrodynamics. This methodology integrates a variety of field data and models, specifically:

• Monitoring - multi-year embayment nutrient sampling

• Hydrodynamics
  - Embayment bathymetry (depth contours throughout the embayment)
  - Site-specific tidal record (timing and height of tides)
  - Water velocity records (in complex systems only)
  - Hydrodynamic model

• Watershed Nitrogen Loading
  - Watershed delineation
  - Stream flow (Q) and N load
  - Land-use analysis (GIS)
  - Watershed N model

• Embayment TMDL - Synthesis
  - Linked Watershed-Embayment Nitrogen Model
  - Salinity surveys (for linked model validation)
  - Rate of N recycling within embayment
  - Dissolved oxygen record
  - Macrophyte (eelgrass) survey
  - Infaunal survey (in complex systems)

Application of the Linked Watershed-Embayment Model

The approach developed by the MEP for applying the linked model to specific embayments for the purpose of developing target N loading rates includes:

1) Selecting one or two stations within the embayment system located close to the inland-most reach or reaches which typically have the poorest water quality within the system. These are called "sentinel" stations;

2) Using site-specific information and a minimum of three years of sub-embayment-specific data to select target threshold N concentrations for each sub-embayment. This is done by refining the draft target threshold N concentrations that were developed as the initial step of the MEP process. The target threshold N concentrations that were selected generally occur in higher quality waters near the mouth of the embayment system;

3) Running the calibrated water quality model using different watershed N loading rates to determine the loading rate that will achieve the target threshold N concentration at the sentinel station. Differences between the modeled N load required to achieve the target threshold N concentration and the present watershed N load represent N management goals for restoration and protection of the embayment system as a whole.

Previous sampling and data analyses and the modeling activities described above resulted in four major outputs that were critical to the development of the TMDL. Two outputs are related to **N concentration in the embayment:**

1) The present N concentrations in the sub-embayments
2) Site-specific target threshold N concentrations

And, two outputs are related to **N loadings:**

1) The present N loads to the sub-embayments
2) Load reductions necessary to meet the site specific target threshold N concentrations

In summary: if the water quality standards are met by reducing the N concentration (and thus the N load) at the sentinel station(s), then the water quality goals will be met throughout the entire system. A brief overview of each of the outputs follows:

Nitrogen Concentrations in the Sub-embayments

1) Observed "present" conditions:

Five monitoring locations were sampled in the Parkers River Embayment System between 2002 and 2008 by the Yarmouth Water Quality Monitoring Program to determine average concentrations of N in this system (Figure 5). The average of the yearly average nitrogen concentrations in the embayment system range from 0.66 mg/L N in the well flushed lower Parkers River (Station PR-3) to 0.99 mg/L N in the less well flushed Seine Pond (Station PR-5) (Table 4).

2) Modeled site-specific target threshold N concentration

A major component of TMDL development is the determination of the maximum concentrations of N (based on field data) that can occur without causing unacceptable impacts to the aquatic environment. Prior to conducting their analytical and modeling activities, SMAST selected appropriate nutrient-related environmental indicators and tested the qualitative and quantitative relationship between those indicators and N concentrations. The Linked Model was then used to determine site-specific target threshold N concentrations by using the specific physical, chemical, and biological characteristics of each subembayment.

As listed in Table 4 below, the site-specific target threshold N concentration is 0.42 mg/L. The findings of the analytical and modeling investigations to determine this target threshold nitrogen concentration for the embayment system are discussed below.

Table 4: Measured Nitrogen Concentrations for the Parkers River and Sentinel Station Target Threshold Nitrogen Concentration for the Herring River Estuarine System (from Howes *et. al*, 2010).

Sub-Embayment	Station	**Mean**[1] (mg/L N)	Standard Deviation	Number Samples	Target Threshold Nitrogen Concentration (mg/L)
Seine Pond - Upper	PR-5	0.994	0.229	24	0.50[2]
Seine Pond - Lower	PR-1	0.948	0.225	34	
Upper Parkers River	PR-2	0.776	0.216	37	-
Lower Parkers River	PR-3	0.663	0.167	32	**0.42**[2]
Lewis Pond	PR-4	0.868	0.227	36	0.60[2]
Nantucket Sound	NTKS	0.294	0.062	4	

[1] Mean values are calculated as the average of the separate yearly means. Data collected in the summers of 2002 through 2008.

[2] Primary sentinel station threshold for eelgrass restoration in lower Parkers River; secondary check stations for benthic infauna threshold located in Seine Pond and Lewis Pond.

The principal habitat degradation within the Parkers River Embayment system relates to loss of eelgrass beds in the lower Parkers River and a poor infauna community in Seine Pond. These impacts combined with other indicators including oxygen depletion, chlorophyll-*a* and total nitrogen indicate aquatic health degradation due to nitrogen enrichment (Table 2). Restoration of eelgrass to the Parkers River and the benthic infaunal community in Seine Pond are the primary targets for the restoration of the estuarine system. Given the greater nitrogen sensitivity of eelgrass and its priority in estuarine restoration, the primary sentinel station was located in the Parkers River at the upper most extent of previously documented eelgrass beds (Figure 6). The site-specific target threshold N concentration for the Parker River Embayment system is 0.42 mg/L N.

The target threshold N concentration at the primary sentinel station represents the average water column concentration of N that will support the habitat quality conditions supportive of eelgrass. In this system, high habitat quality was defined as healthy eelgrass beds, diverse benthic animal communities and dissolved oxygen levels that would support Class SA waters. The restoration of eelgrass in the Parkers River will also allow for the restoration of severely degraded aquatic habitat in the upper river (north of Rte 28).

Eelgrass has not been found in the Parkers River since prior to 1995 and the target threshold N for the primary sentinel station was based on a comparison to similar local basins with eelgrass.

Bournes Pond Estuary is supportive of eelgrass (largely confined to the lower estuarine basin) with nitrogen concentrations of 0.45 mg/L N within the mainstem channel to upper estuary and a lower concentration of 0.42 mg/L N in Israel's Cove, an open water basin. The tidally averaged nitrogen concentration within the main channel of Bournes Pond is 0.426 mg/L N and healthy eelgrass beds are found. Patches of eelgrass are found at tidally averaged nitrogen concentrations of 0.481 mg/L N. Green Pond provides another benchmark with which to generate a target threshold N concentration. Sparse eelgrass is found at tidally averaged total nitrogen levels of 0.41 mg/L N. Historically the eelgrass beds within the Parkers River have been characterized as "patchy and like similar basins, found mainly in more stable shallow areas" (Howes *et. al*, 2010 , pg. 136). The results of the MEP project for the Parkers River Embayment system suggest a target threshold nitrogen concentration of 0.42 mg/L N in order to restore eelgrass to the "margins of the tidal channel where light reaches the sediments at higher TN levels than at deeper areas" (Howes *et. al*, pg. 136).

Secondary nitrogen target values were also determined for Seine Pond and Lewis Pond in order to support healthy infaunal habitat. Previous work during the MEP project has helped inform the appropriate target threshold nitrogen to support a healthy infaunal habitat. Locations with moderately impacted benthic communities in the lower Parkers River were found to have average ebb tide total nitrogen in the range of 0.65 mg/L N. MEP technical staff have observed healthy infaunal habitat in enclosed basins including Perch Pond, Bournes Pond and Popponesset Bay with total nitrogen levels less than 0.5 mg/L N. The MEP project has found moderately impaired habitat at approximately 0.6 mg/L N. Previous MEP work has found moderate impairment in the Wareham River with observed TN levels ranging between 0.535-0.600 mg/L N. Similarly in the Centerville River system in the main channel moderate impairment was found at 0.543 mg/L N (tidally averaged). The most appropriate benchmark for Lewis Pond was determined to be the Scudder Bay section of the Centerville River system, which is a similar salt marsh dominated system. This area showed impairment at 0.526 mg/L N (tidally averaged). Given the observed relationship between total nitrogen levels and benthic impairment, the MEP technical team concluded that a healthy infaunal habitat could be supported in Seine Pond and the upper Parkers River at an upper limit of 0.50 mg/L N (tidally averaged). Lewis Pond, given its "shallow nature and its function as primarily a salt marsh basin", has been assigned a target threshold nitrogen of less than 0.60 mg/L N (tidally averaged). This higher level is due to the shallow nature of Lewis Pond compared to Scudder Bay and similar to the threshold for the upper Mashpee River which also supports a shallow salt marsh habitat. (Howes *et. al*, 2010, pg. 137).

The secondary nitrogen targets were used to make sure that acceptable conditions were present in the tributary basins (Seine Pond and Lewis Pond) when the nitrogen threshold was met at the sentinel station in the lower Parkers River. The values act as a "check on the acceptability of conditions in tributary basins (Seine Pond average of PR-1 & PR -5; Lewis Pond PR-4) at the point that the threshold level is attained at the sentinel station within the lowers Parkers River" (Howes *et. al*, 2010, pg. 137, Figures 6, 7). Secondary sentinel stations corresponding with the secondary nitrogen targets in Seine Pond and Lewis Pond have been established (Figure 6). Ultimately the goal is to restore eelgrass to the Parkers River and healthy infaunal habitat throughout the Parkers River Embayment system. It is believed that by achieving the target threshold nitrogen target at the primary sentinel station that nitrogen levels (tidally averaged) nitrogen levels will also be in an acceptable range to meet the secondary nitrogen targets established to support healthy infaunal habitat.

Present Attenuated Nitrogen Loadings to the Embayment

In addition to the determination of watershed loadings, the MEP approach allows the determination of attenuated nitrogen loadings to the Parkers River Embayment System. Nitrogen removed from the system as it passes through the watershed through natural, chemical and biological processes is said to be attenuated. The highest controllable source of N loading is from on-site wastewater treatment systems (85%) (Figure ES-1). Other much smaller controllable N sources include fertilizers, impervious surface runoff and the Yarmouth WWTF. Sediments and atmospheric deposition are not considered controllable (Figure ES-1). Nitrogen loading from the nutrient-rich sediments (referred to as benthic flux) can be significant in estuarine systems (approximately 29% of the total N load from all sources in this system). However, the magnitude of the benthic contribution is related to the watershed load. Therefore, reducing the incoming watershed load should reduce the benthic flux over time. A breakdown of attenuated N loading, by source, is presented in Table 5. This table is based on data from Table ES-1 of the MEP technical report for this embayment system (Howes *et. al*, 2010).

As previously indicated, the present N loadings to Parkers River System must be reduced in order to restore conditions and to avoid further nutrient-related adverse environmental impacts. The critical final step in the development of the TMDL is modeling and analysis to determine the nitrogen loadings required to achieve the target threshold N concentration.

(report continued next page)

Figure 5: MEP Water Quality Sampling Stations in Parkers River Embayment System
(Howes *et. al*, 2010)

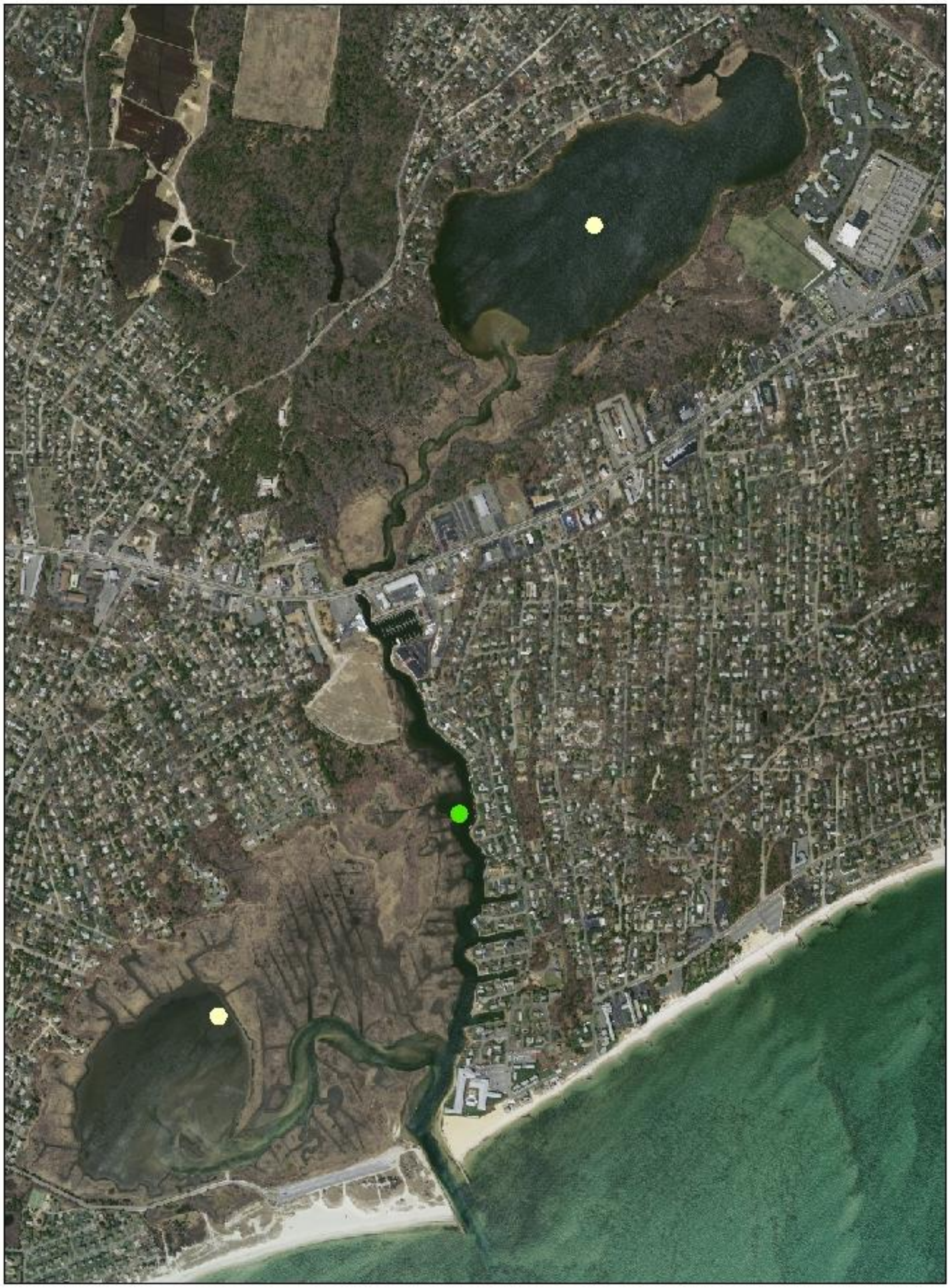

Figure 6: Sentinel Station in the Parkers River Embayment System (Primary sentinel station = green dot, secondary station = yellow dot).

Table 5: Present Attenuated Nitrogen Loading to the Parkers River Embayment System (from Howes *et. al*, 2010)

Embayment	Present Land Use Load N[1] (kg/day)	Present Attenuated Septic System Load N (kg/day)	Present Attenuated WWTF Load N[2] (kg/day)	Present Total Attenuated Watershed Load N[3] (kg/day)	Direct Atmospheric Deposition N[4] (kg/day)	Present Net Benthic Flux N (kg/day)	Total N Load from All Sources[5] (kg/day)
Seine Pond	3.57	16.992	-	20.562	1.096	-5.82	15.838
Upper Parkers River	3.791	12.34	0.277	16.408	0.049	0.775	17.233
Lower Parkers River	0.901	11.751	-	12.652	0.266	28.42	41.338
Lewis Pond	2.718	14.682	-	17.4	0.616	5.698	23.714
Parkers River System Total	11.258	55.764	0.277	67.022	2.027	29.074	98.123

1- composed of non-wastewater loads, e.g. fertilizer and runoff and natural surfaces and atmospheric deposition to lakes, wetlands and natural surfaces
2 -existing attenuated wastewater treatment facility discharges to groundwater, Town of Yarmouth Septage Treatment Facility
3 -composed of combined present land use, septic system, and WWTF loadings
4 -atmospheric deposition to embayment surface only
5 -composed of attenuated loadings from natural background, fertilizer, runoff, septic systems and WWTF as well as atmospheric deposition and benthic flux loadings

Nitrogen load reductions necessary for meeting the site-specific target threshold N concentration

The target nitrogen threshold concentration developed by SMAST and summarized above was used in the linked model to determine the amount of total nitrogen mass loading reduction required for restoration of eelgrass and infaunal habitats in the Parkers River Embayment System. Tidally averaged total nitrogen concentrations were used to calibrate the water quality model. Modeled watershed nitrogen loads were sequentially lowered using reductions in septic effluent discharges only until the nitrogen levels reached the threshold level at the sentinel station chosen for the Parker River Embayment System (Figure 7). It is important to note that load reductions can be produced by reduction of any or all sources of N and/or by increasing the natural attenuation of nitrogen within the freshwater systems to the embayment.

The load reductions necessary to achieve the target threshold nitrogen concentration at the primary sentinel station are presented in Table 6. These values represent only one of a suite of potential reduction approaches that need to be evaluated by the Town of Yarmouth. The presentation is to establish the general degree and spatial pattern of reduction that will be required for restoration of this N impaired embayment. Other alternatives may also achieve the desired target threshold N concentration as well and can be explored using the MEP modeling approach. The Town of Yarmouth should take any reasonable actions to reduce the controllable N sources.

Table 6: Present Attenuated Watershed Nitrogen Loading Rates, Calculated Loading Rates that are Necessary to Achieve Target Threshold Nitrogen Concentrations, and the Percent Reductions of the Existing Loads Necessary to Achieve the Target Threshold Loadings System (from Howes *et. al*, 2010)

Subembayment	Present Attenuated Watershed Load[1] (kg/day)	Target Threshold Watershed Load[2] (kg/day)	Percent watershed reductions needed to achieve target threshold loads
Seine Pond	20.562	4.080	-80.2%
Upper Parkers River	16.408	4.439	-72.9%
Lower Parkers River	12.652	1.489	-88.2%
Lewis Pond	17.400	3.452	-80.2%
Total	67.022	13.459	-79.9%

1- Composed of wastewater from septic systems, fertilizer, runoff from impervious surfaces, atmospheric deposition to freshwater waterbodies and wastewater from one wastewater treatment facility. This load does not include direct atmospheric deposition onto estuarine surfaces or benthic regeneration.
2 -Target threshold watershed load is the load from the watershed needed to meet the embayment target threshold N concentration. Includes natural background.

Table 7 summarizes the present attenuated loadings from septic systems and the necessary reduction in septic loads needed to achieve the target threshold N concentration in the Parkers River embayment system under the scenario modeled here. A 96.10% overall reduction in present septic loading to the Parkers River Embayment system achieved the target threshold N concentration of 0.42 mg/L at the sentinel station, time averaged over the summer period.

Table 7: Summary of the Present Septic System Loads and the Loading Reductions that would be Necessary to Achieve the TMDL by Reducing Septic System Loads Alone (excerpted from Howes *et. al*, 2010)

Subembayment	Present septic load (kg/day)	Threshold septic load (kg/day)	Threshold septic load % change
Seine Pond	16.99	0.51	-97.0%
Upper Parkers River	12.34	0.37	-97.0%
Lower Parkers River	11.75	0.59	-95.0%
Lewis Pond	14.68	0.73	-95.0%
Total	55.76	2.20	-96.1%

Total Maximum Daily Loads

A total maximum daily load (TMDL) identifies the loading capacity of a waterbody for a particular pollutant and allocates loads among all known pollutant sources such that water quality standards can be met. Estuary TMDLs are established to protect and/or restore the estuarine ecosystem, including eelgrass, the leading indicator of ecological health, thus meeting water quality goals for aquatic life support. Because there are no "numerical" water quality standards for N, the TMDL for the Parkers River Embayment System is aimed at determining the loads that would correspond to specific N concentrations determined to be protective of the water quality and ecosystems.

The development of a TMDL requires detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time) for each waterbody system. The results of the mathematical model are correlated with estimates of impacts on water quality, including negative impacts on eelgrass (the primary indicator), as well as dissolved oxygen, chlorophyll *a* and benthic infauna.

The TMDL can be defined by the equation: ***TMDL = BG + WLAs + LAs + MOS***

Where:
TMDL = Total Maximum Daily Load is the loading capacity of receiving water
BG = natural background
WLAs = Waste Load allocation is the portion allotted to point sources
LAs = Load Allocation is the portion allotted to (cultural) non-point sources
MOS = margin of safety

Background loading

Natural background N loading is included in the loading estimates, but is not quantified and presented separately. Background loading was calculated on the assumption that the entire watershed is forested with no anthropogenic sources of N. It is accounted for in this study but not defined as a separate component. Refer to Table ES-1 of the MEP Technical Report for estimated loading due to natural conditions.

Wasteload Allocations

Waste load allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater. In the Parkers River Estuarine System there are no permitted surface water discharges in the watershed with the exception of stormwater. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of storm water be included in the waste load component of the TMDL.

Stormwater

For purposes of the Parkers River TMDLs, MassDEP also considered the nitrogen load reductions from regulated MS4 sources necessary to meet the target nitrogen concentrations. In estimating the nitrogen loadings from regulated stormwater sources, MassDEP considered that most stormwater runoff in the MS4 communities is not discharged directly into surface waters, but, rather, percolates into the ground. The geology on Cape Cod and the Islands consists primarily of glacial outwash sands and gravels, and water moves rapidly through this type of soil profile. A systematic survey of stormwater conveyances on Cape Cod and the Islands was never undertaken prior to the MEP study used in the development of this TMDL. Nevertheless, most catch basins on Cape Cod and the Islands are known to MassDEP to have been designed as leaching catch basins in light of the permeable overburden. MassDEP, therefore, recognized that most stormwater that enters a catch basin in the regulated area will percolate into the local groundwater table rather than directly discharge to a surface waterbody.

As described in the Methodology Section (above), the Linked Model accounts for storm water loadings and groundwater loading in one aggregate allocation as a non-point source. However, MassDEP also considered that some stormwater collected in the regulated area is discharged directly to surface waters through outfalls.

In the absence of specific data or other information to accurately quantify stormwater discharged directly to surface waters, MassDEP assumed that all impervious surfaces within 200 feet of the shoreline, as calculated from MassGIS data layers, would discharge directly to surface waters, whether or not it in fact did so. MassDEP selected this approach because it considered it unlikely that any stormwater collected farther than 200 ft. from the shoreline would be directly discharged into surface waters. Although the 200 foot approach provided a gross estimate, MassDEP considered it a reasonable and conservative approach given the lack of pertinent data and information about MS4 systems on Cape Cod. For the Parker River Estuarine System this calculated stormwater WLA based on the 200 foot buffer is 0.22 kg/day N. This WLA amounts to 1% of the total N load to the Parkers River system (see Appendix C for details). This conservative load is a negligible amount of the total nitrogen load to this embayment when compared to other sources.

Load Allocations

Load allocations (LA) identify the portion of loading capacity allocated to existing and future nonpoint sources. In the case of the Parkers River embayment system, the controllable nonpoint watershed source loadings are primarily from septic systems. Additional N sources include stormwater runoff (except from impervious cover within 200 feet of the waterbody which is defined above as part of the waste load as discussed above), fertilizers, the one WWTF (Town of Yarmouth, groundwater discharge) and atmospheric deposition (to both freshwater and estuarine waterbodies and natural surfaces). These sources together are all considered part of the watershed load of nitrogen. Watershed sources of controllable attenuated nitrogen were detailed above in Table 5 and also Figure 1.

Generally, stormwater that is subject to the EPA Phase II Program would be considered a part of the wasteload allocation, rather than the load allocation. As presented in Chapter IV, V, and VI, of the MEP Technical Report, on Cape Cod and the Islands the vast majority of stormwater percolates into the aquifer and enters the embayment system through groundwater. Given this, the TMDL accounts for stormwater loadings and groundwater loadings in one aggregate allocation as a non-point source. Continued implementation of the Phase II program in Yarmouth will help to identify and control stormwater loads through the application of Best Management Practices (BMPs).

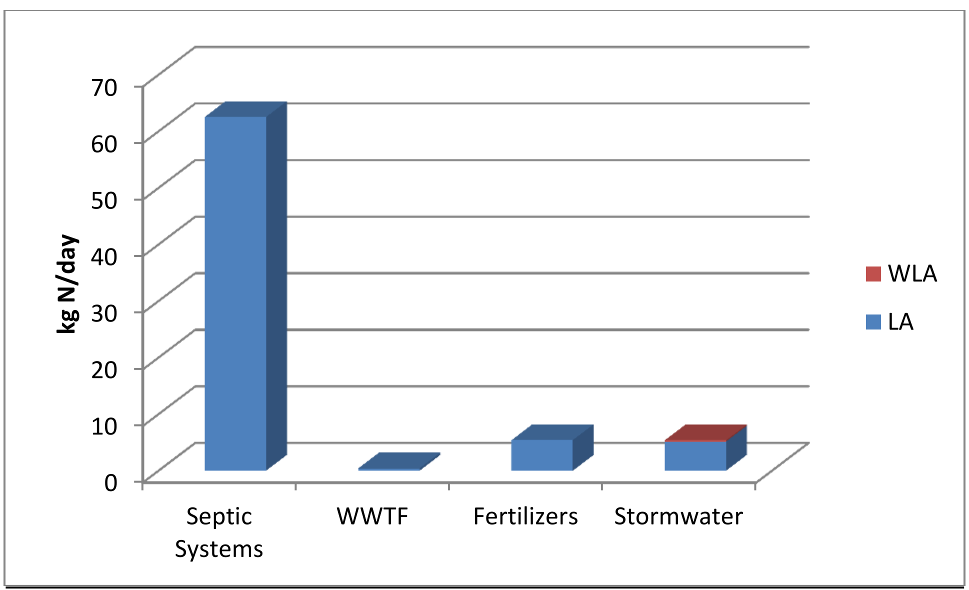

Figure 7: Parkers River Estuarine System Locally Controllable N Loads by Source

In general, benthic N flux is a function of N loading and particulate organic N (PON). Projected benthic fluxes are based upon projected PON concentrations and watershed N loads and are calculated by multiplying the present N flux by the ratio of projected PON to present PON using the following formulae:

Projected N flux = (present N flux) (PON projected / PON present)

When: $PON\ projected = (R_{load})\ (D_{PON}) + PON_{present\ offshore}$

When: $R_{load} = (projected\ N\ load) / (Present\ N\ load)$

And: D_{PON} is the PON concentration above background determined by:

$$D_{PON} = (PON_{present\ embayment} - PON_{present\ offshore})$$

Typically, the projected benthic fluxes are lower than the existing benthic input because projected reductions of N loadings from the watershed will result in reductions of nutrient concentrations in the sediments and therefore, over time, reductions in loadings from the sediments will occur.

For Seine Pond, the MEP study reported negative benthic flux load (Table 5, above). Negative benthic flux was incorporated into the water quality model to determine the watershed N load and the necessary watershed load reductions, however MassDEP has determined that negative loads are not appropriate for incorporating into the TMDL. The TMDL by definition is for regulation of loading inputs and, as such, a negative number for a load does not apply. Accordingly, negative benthic flux loads were set to zero for determination of the TMDL.

The loadings from atmospheric sources incorporated into the TMDL are the same rates presently occurring because, as discussed above, local control of atmospheric loadings is not considered feasible.

Margin of Safety

Statutes and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality [CWA para 303 (d)(20©, 40C.G.R. para 130.7©(1)]. The MOS must be designed to ensure that any uncertainties in the data or calculations used to link pollutant sources to water quality impairment modeling will be accounted for in the TMDL and ensure protection of the beneficial uses. The EPA’s 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. An explicit MOS quantifies an allocation amount separate from other Load and Wasteload Allocations. An explicit MOS can incorporate reserve capacity for future unknowns, such as population growth or effects of climate change on water quality. An implicit MOS is not specifically quantified but consists of statements of the conservative assumptions used in the analysis. The MOS for the Parkers River Estuarine System TMDL is implicit. MassDEP used conservative assumptions to develop numeric model applications that account for the MOS. These assumptions are described below, and they account for all sources of uncertainty, including the potential impacts of changes in climate.

While the general vulnerabilities of coastal areas to climate change can be identified, specific impacts and effects of changing estuarine conditions are not well known at this time (http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html). Because the science is not yet available, MassDEP is unable to analyze climate change impacts on streamflow, precipitation, and nutrient loading with any degree of certainty for TMDL development. In light of these uncertainties and informational gaps, MassDEP has opted to address all sources of uncertainty through an implicit MOS. MassDEP does not believe that an explicit MOS approach is appropriate under the circumstances or will provide a more protective or accurate MOS than the implicit MOS approach, as the available data simply does not lend itself to characterizing and estimating loadings to derive numeric allocations within confidence limits. Although the implicit MOS approach does not expressly set aside a specific portion of the load to account for potential impacts of climate change, MassDEP has no basis to conclude that the conservative assumptions that were used to develop the numeric model applications are insufficient to account for the lack of knowledge regarding climate change.

Conservative assumptions that support an implicit MOS:

1. Use of conservative data in the linked model

The watershed N model provides conservative estimates of N loads to the embayments. Nitrogen transfer through direct groundwater discharge to estuarine waters is based upon studies indicating negligible aquifer attenuation and dilution, i.e. 100% of load enters embayment. This is a conservative estimate of loading because studies have also shown that in some areas less than 100% of the load enters the estuary. In this context, "direct groundwater discharge" refers to the portion of fresh water that enters an estuary as groundwater seepage into the estuary itself, as opposed to the portion of fresh water that enters as surface water inflow from streams, which receive much of their water from groundwater flow. Nitrogen from the upper watershed regions, which travel through ponds or wetlands, almost always enter the embayment via stream flow, are directly measured (over 12-16 months) to determine attenuation. In these cases the land-use model has shown a slightly higher predicted N load than the measured discharges in the streams/rivers that have been assessed to date. Therefore, the watershed model as applied to the surface water watershed areas again presents a conservative estimate of N loads because the actual measured N in streams was lower than the modeled concentrations.

The hydrodynamic and water quality models have been assessed directly. The hydrodynamic modeling conducted during the MEP project showed strong agreement between measured and modeled tides. The error associated with tidal height was less than the accuracy of the tidal gage (<0.032 ft). In addition to tidal height, the MEP project ascertained the relationship between model predictions of volumetric exchange (flushing) and as measured by field measurement of instantaneous discharge. Instantaneous discharge was performed using acoustic doppler current profilers (ADCP) at two key locations within the embayment. Two transects were conducted at these key locations, in the Parkers River immediately south of the confluence with Lewis Pond and in the Parkers River immediately south of the marina near Route 28 (Howes *et. al*., 2010). The R^2 correlation coefficient between measured ADCP data and modeled values was 0.89 and

0.81 respectively for the two transects. The good fit between the measured and modeled hydrodynamics values indicates a robust model and confidence in the model's outputs.

With regards to the water quality model, it is possible to conduct a quantitative assessment of the model outputs as fitted to the measured nitrogen concentrations. The computed root mean square error for this modeling effort is 0.08 mg/L and indicates a good fit between measured and modeled data (Howes *et. al.*, 2010). Since the water quality model incorporates all of the outputs from the other models, this good fit indicates a high degree of certainty in the final result. In addition to this the model shows a good fit between predicted and modeled nitrogen values near the primary sentinel station (PR-2, Figure 6). The high level of accuracy of the model provides a high degree of confidence in the output; therefore, less of a margin of safety is required.

Similarly, the water column N validation dataset was also conservative. The model is calibrated to measured water column N and validated to salinity. However, the model predicts average summer N concentrations. The very high or low measurements are marked as outliers. The effect is to make the N threshold more accurate and scientifically defensible. If a single measurement two times higher than the next highest data point in the series raises the average 0.05 mg N/L, this would allow for a higher "acceptable" load to the embayment. Marking the very high outlier is a way of preventing a single and rare bloom event from changing the N threshold for a system. This effectively strengthens the data set so that a higher margin of safety is not required.

Finally, the predicted reductions of the amount of N released from the sediments are most likely underestimates, i.e. conservative. The reduction is based solely on a reduced deposition of particulate organic nitrogen (PON) due to lower primary production rates under the reduced N loading in these systems. As the N loading decreases and organic inputs are reduced it is likely that rates of coupled remineralization-nitrification, denitrification and sediment oxidation will increase.

Benthic regeneration of N is dependent upon the amount of PON deposited to the sediments and the percentage that is regenerated to the water column versus being denitrified or buried. The regeneration rate projected under reduced N loading conditions was based upon two assumptions:(1) PON in the embayment in excess of that of inflowing tidal water (boundary condition) results from production supported by watershed N inputs; and (2) Presently enhanced production will decrease in proportion to the reduction in the sum of watershed N inputs and direct atmospheric N input. The latter condition would result in equal embayment versus boundary condition production and PON levels if watershed N loading and direct atmospheric deposition could be reduced to zero (an impossibility of course). This proportional reduction assumes that the proportion of remineralized N will be the same as under present conditions, which is almost certainly an underestimate. As a result, future N regeneration rates are overestimated which adds to the margin of safety.

In the case of N attenuation by freshwater ponds, attenuation was derived when available from measured N concentrations, pond delineations and pond bathymetry. Information to calculate nitrogen attenuation was only available for one freshwater pond, Long Pond. All other ponds analyzed during the MEP project were assigned a conservative attenuation rate of 50%.

Some of the nitrogen loading factors used as part of the watershed nitrogen loading model may be overestimates. The nitrogen loading calculations are based on a wastewater engineering assumption that 90% of water used is converted to wastewater. Actual water use and conversion studies in the area have shown that this conversion rate is conservative adding to the margin of safety.

2. Conservative sentinel station/target threshold nitrogen concentration

Conservatism was used in the selection of the sentinel stations and target threshold N concentration. Stations were chosen that had stable eelgrass or benthic animal (infaunal) communities, and not those just starting to show impairment, which would have slightly higher N concentrations. Meeting the target threshold nitrogen concentration at the sentinel station will result in reductions of N concentrations in the rest of the system.

3. Conservative approach

The target loads were based on tidally averaged N concentrations on the outgoing tide, which is the worst case condition because that is when the N concentrations are the highest. The N concentrations will be lower on the flood tides; therefore, this approach is conservative.

Finally, the linked model accounted for all stormwater loadings and groundwater loadings in one aggregate allocation as a non point source and this aggregate load is accounted for in the load allocation. The method of calculating the WLA in the TMDL for regulated stormwater was conservative as it did not disaggregate this negligible load from the modeled stormwater LA, hence this approach further enhances the margin of safety.

In addition to the margin of safety within the context of setting the N threshold levels, described above, a programmatic margin of safety also derives from continued monitoring of these subembayments to support adaptive management. This continuous monitoring effort provides the ongoing data to evaluate the improvements that occur over the multi-year implementation of the N management plan. This will allow refinements to the plan to ensure that the desired level of restoration is achieved.

Seasonal Variation

Since the TMDL for this embayment system is based on the most critical time period, i.e. the summer growing season, the TMDL is protective for all seasons. Nutrient loads to the embayment as determined during the MEP project are based on annual loads for two reasons. The first is that primary production in coastal waters can peak in both the late winter-early spring and in the late summer-early fall periods. Second, as a practical matter, the types of controls necessary to control the N load, the nutrient of primary concern, by their very nature do not lend themselves to intra-annual manipulation since the majority of the N is from non-point sources. Thus, the annual loads make sense, since it is difficult to control non-point sources of nitrogen on a seasonal basis and that nitrogen sources can take considerable time to migrate to impacted waters. These annual loads have generally been described as daily loads for the purpose of this TMDL by dividing annual loads by 365 (the number of days in a year).

TMDL Values for the Parkers River Embayment System

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of the embayment were calculated by considering all sources of N grouped by natural background, point sources and non-point sources. A more meaningful way of presenting the loadings data from an implementation perspective is presented in Table 8. A summary of TMDLs developed for this embayment system can be found in Appendix D.

In this table the non-controllable N loadings from the atmosphere and sediments are listed separately from the target watershed threshold loads which are composed of natural background N along with locally controllable N from the on-site subsurface wastewater disposal systems, WWTPs, farm animals, stormwater runoff and fertilizer sources. For the Parkers River system the TMDLs were calculated by projecting reductions in locally controllable septic systems in the subwatersheds of the upper and lower Parkers River, Seine Pond and Lewis Pond (Table 7). The goals of these TMDLs are to achieve the identified target threshold N concentration at the identified sentinel station. The target loads identified in Table 8 represent one alternative-loading scenario to achieve that goal but other scenarios may be possible and approvable as well.

Table 8: Total Maximum Daily Loads for the Parkers River Embayment System

Sub-embayment	Target Threshold Watershed Load[1] (kg/day)	Atmospheric Deposition (kg/day)	Projected Benthic Load[2] (kg/day)	TMDL[3] (kg/day)
Seine Pond	4.08	1.10	-	**5.18**
Upper Parkers River	4.44	0.05	0.41	4.90
Lower Parkers River	1.49	0.27	16.26	18.02
Parkers River				**22.92**
Lewis Pond	3.45	0.62	3.30	**7.37**
Total	13.46	2.03	19.97	**35.47**

[1] Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentration identified in Table 6.
[2] Projected sediment N loadings obtained by reducing the present loading rates (Table 5) proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON. (Negative fluxes set to zero.)
[3] Sum of target threshold watershed load, atmospheric deposition and benthic load.

Implementation

The critical element of this TMDL process is achieving the sentinel station specific N concentrations presented above that are necessary for the restoration and protection of water quality and eelgrass habitat within the Parkers River embayment system. In order to achieve those target concentrations, N loading rates must be reduced throughout these four sub-embayments. Target watershed threshold loads are detailed in Table 6. If these threshold loads are achieved, this embayment will be protected.

Septic Systems:
Table 7 presents a load reducing scenario based solely on reducing the septic loads from the Parkers River Embayment watershed. As previously noted, this loading reduction scenario is not the only way to achieve the target N concentrations. The Town of Yarmouth is encouraged to explore other loading reduction scenarios through additional modeling as part of the Comprehensive Wastewater Management Plan (CWMP). It must be demonstrated, however, that any alternative implementation strategies will be protective of Parkers River embayment system, and that none of the embayment will be negatively impacted. To this end, additional linked model runs can be performed by the MEP to assist the planning efforts of the Town in achieving target N loads that will result in the desired threshold concentrations.

The CWMP should include a schedule of the selected strategies and estimated timelines for achieving those targets. However, the MassDEP realizes that an adaptive management approach may be used to observe implementation results over time and allow for adjustments based on those results. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under the Clean Water Act Section 208. If a community chooses to implement TMDL measures without a CWMP it must demonstrate that these measures will achieve the target threshold N concentration. (Note: Communities that choose to proceed without a CWMP will not be eligible for State Revolving Fund loans.)

Because the vast majority of controllable N load is from individual on-site subsurface wastewater disposal systems for private residences, the CWMP should assess the most cost-effective options for achieving the target N watershed loads, including but not limited to, sewering and treatment for N control of sewage and septage at either centralized or de-centralized locations, and denitrifying systems for all private residences. Table 8 lists the target watershed threshold loads for this embayment. If this threshold load is achieved, the embayment will be protected.

Stormwater:
EPA and MassDEP authorized most of the watershed community of Yarmouth for coverage under the NPDES Phase II General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. EPA and MassDEP reissued the MS4 permit in April 2016. The reissued permit takes effect on July 1, 2017. The NPDES permits EPA has issued in Massachusetts to implement the Phase II Stormwater program do not establish numeric effluent limitations for stormwater discharges, rather, they establish narrative requirements, including best management practices, to meet the following six minimum control measures and to meet State Water Quality Standards.

1. Public education and outreach particularly on the proper disposal of pet waste,
2. Public participation/involvement,

3. Illicit discharge detection and elimination,
4. Construction site runoff control,
5. Post construction runoff control, and
6. Pollution prevention/good housekeeping.

As part of their applications for Phase II permit coverage, communities must identify the best management practices they will use to comply with each of these six minimum control measures and the measurable goals they have set for each measure. Therefore, compliance with the requirements of the Phase II stormwater permit in the Town of Yarmouth will contribute to the goal of reducing the nitrogen load as prescribed in this TMDL for the Parkers River estuarine system watershed.

According to the 2015 Annual Phase II MS4 Stormwater report to EPA, Yarmouth contracted with SMAST to study the impacts of improved flushing of the Parkers River/Swan Pond watershed. The study determined that widening the bridge on Route 28 at Parkers River will improve water as well as restore the large salt marsh to the north. Yarmouth worked with the Division of Ecological Restoration and Applied Coastal to determine the ideal bridge opening size. Bridge design plans are continuing and construction on the bridge may begin as early as fall 2016.

Yarmouth is continuing to map the drainage systems upgradient of stormwater outlets and has begun determining watersheds for each of those outlets. The annual reports indicate that they continue to update stormwater drainage systems to Phase II standards. In addition, the Town conducts an ongoing public outreach campaign that includes stormdrain decals, website, posters, handouts, mailers and flyers with information on various pollution prevention activities (e.g., hazardous waste collections) and regulations. The town completed camera inspection and repair of the two largest drainage outlets.

Climate Change

MassDEP recognizes that long-term (25+ years) climate change impacts to southeastern Massachusetts, including the area of this TMDL, are possible based on known science. Massachusetts Executive Office of Energy and Environmental Affairs 2011Climate Change Adaptation Report: http://www.mass.gov/eea/waste-mgnt-recycling/air-quality/green-house-gas-and-climate-change/climate-change-adaptation/climate-change-adaptation-report.html predicts that by 2100 the sea level could be from 1 to 6 feet higher than the current position and precipitation rates in the Northeast could increase by as much as 20 percent. However, the details of how climate change will affect sea level rise, precipitation, streamflow, sediment and nutrient loading in specific locations are generally unknown. The ongoing debate is not about whether climate change will occur, but the rate at and the extent to which it will occur and the adjustments needed to address its impacts. EPA's 2012 Climate Change Strategy http://water.epa.gov/scitech/climatechange/upload/epa_2012_climate_water_strategy_full_report_final.pdf states: "Despite increasing understanding of climate change, there still remain questions about the scope and timing of climate change impacts, especially at the local scale where most water-related decisions are made." For estuarine TMDLs in southeastern Massachusetts, MassDEP recognizes that this is particularly true, where water quality management decisions and implementation actions are generally made and conducted at the municipal level on a sub-watershed scale.

EPA's Climate Change Strategy identifies the types of research needed to support the goals and strategic actions to respond to climate change. EPA acknowledges that data are missing or not available for making water resource management decisions under changing climate conditions. In addition, EPA recognizes the limitation of current modeling in predicting the pace and magnitude of localized climate change impacts and recommends further exploration of the use of tools, such as atmospheric, precipitation and climate change models, to help states evaluate pollutant load impacts under a range of projected climatic shifts.

In 2013, EPA released a study entitled, "Watershed modeling to assess the sensitivity of streamflow, nutrient, and sediment loads to potential climate change and urban development in 20 U.S. watersheds." (National Center for Environmental Assessment, Washington D.C.; EPA/600/R-12/058F). The closest watershed to southeastern Massachusetts that was examined in this study is a New England coastal basin located between Southern Maine and Central Coastal Massachusetts. These watersheds do not encompass any of the watersheds in the Massachusetts Estuary Project (MEP) region, and it has vastly different watershed characteristics, including soils, geography, hydrology and land use – key components used in a modeling analysis. The initial "first order" conclusion of this study is that, in many locations, future conditions, including water quality, are likely to be different from past experience. However, most significantly, this study did not demonstrate that changes to TMDLs (the water quality restoration targets) would be necessary for the region. EPA's 2012 Climate Change Strategy also acknowledges that the Northeast, including New England, needs to develop standardized regional assumptions regarding future climate change impacts. EPA's 2013 modeling study does not provide the scientific methods and robust datasets needed to predict specific long-term climate change impacts in the MEP region to inform TMDL development.

MassDEP believes that impacts of climate change should be addressed through TMDL implementation with an adaptive management approach in mind. Adjustments can be made as environmental conditions, pollutant sources, or other factors change over time. Massachusetts Coastal Zone Management (CZM) has developed a StormSmart Coasts Program (2008) to help coastal communities address impacts and effects of erosion, storm surge and flooding which are increasing due to climate change. The program, www.mass.gov/czm/stormsmart offers technical information, planning strategies, legal and regulatory tools to communities to adapt to climate change impacts.

As more information and tools become available, there may be opportunities to make adjustments in TMDLs in the future to address predictable climate change impacts. When the science can support assumptions about the effects of climate change on the nitrogen loadings to the Parkers River Estuarine System the TMDL can be reopened, if warranted.

Yarmouth is urged to meet the target threshold N concentrations by reducing N loadings from any and all sources, through whatever means are available and practical, including reductions in stormwater runoff and/or fertilizer use within the watershed through the establishment of local by-laws and/or the implementation of stormwater BMPs, in addition to reductions in on-site subsurface wastewater disposal system loadings.

The Massachusetts Estuaries Project: Embayment Restoration and Guidance for Implementation Strategies (MassDEP 2003) provides N loading reduction strategies that are available to Yarmouth and that could be incorporated into the implementation plans. The following topics related to N reduction are discussed in the Guidance:

- Wastewater Treatment
    - On-Site Treatment and Disposal Systems
    - Cluster Systems with Enhanced Treatment
    - Community Treatment Plants
    - Municipal Treatment Plants and Sewers
- Tidal Flushing
    - Channel Dredging
    - Inlet Alteration
    - Culvert Design and Improvements
- Stormwater Control and Treatment *
    - Source Control and Pollution Prevention
    - Stormwater Treatment
- Attenuation via Wetlands and Ponds
- Water Conservation and Water Reuse
- Management Districts
- Land Use Planning and Controls
    - Smart Growth
    - Open Space Acquisition
    - Zoning and Related Tools
- Nutrient Trading

*The Town of Yarmouth is one of the 237 communities in Massachusetts currently covered under the Phase II Stormwater program requirements.

As an additional modeling scenario requested by the town, Howes *et. al* (2010) analyzed several scenarios that involved increasing the width and depth of the Route 28 culvert to increase tidal flushing in the upper portion of the system, including Seine Pond. Their analysis indicated that the optimized culvert scenario (widening the channel from 18 feet to 30 feet and deepening) would significantly reduce the amount of watershed load that needed to be removed to achieve the target threshold TN concentrations compared to what was determined for the existing culvert. For example, instead of removing nearly 100% of the septic load with the existing culvert in order to achieve the threshold TN concentration, approximately 63% of the septic load would need to be removed with the modified culvert. In October 2013 the United States Fish and Wildlife service awarded $3,718,000 for the Parkers River Restoration project in Yarmouth that will restore tidal hydrology to the Parkers River system as well as "enhance diadromous fish passage through replacement of two underperforming fish passage structures" by replacing the tidally restricting Route 28 culvert (MassDEP 2013b).

Monitoring Plan

MassDEP is of the opinion that there are two forms of monitoring that are useful to determine progress towards achieving compliance with the TMDL. MassDEP's position is that implementation will be conducted through an iterative process where adjustments may be needed in the future. The two forms of monitoring include: 1) tracking implementation progress as approved in the town CWMP plan (as appropriate); and 2) monitoring ambient water quality conditions, including but not limited to, the sentinel station identified in the MEP Technical Report.

The CWMP will evaluate various options to achieve the goals set out in the TMDL and Technical Report. It will also make a final recommendation based on existing or additional modeling runs, set out required activities and identify a schedule to achieve the most cost effective solution that will result in compliance with the TMDL. Once approved by MassDEP, tracking progress on the agreed-upon plan will, in effect, also be tracking progress towards water quality improvements in conformance with the TMDL.

Relative to water quality, MassDEP believes that an ambient monitoring program much reduced from the data collection activities needed to properly assess conditions and to populate the model will be important to determine actual compliance with water quality standards. Although the TMDL load values are not fixed the target threshold N concentrations at the sentinel stations are fixed. Through discussions amongst the MEP it is generally agreed that existing monitoring programs which were designed to thoroughly assess conditions and populate water quality models can be substantially reduced for compliance monitoring purposes. Although more specific details need to be developed on a case by case basis, MassDEP's current thinking is that about half the current effort (using the same data collection procedures) would be sufficient to monitor compliance over time and to observe trends in water quality changes. In addition, the benthic habitat and communities would require periodic monitoring on a frequency of about every 3-5 years. Finally, in addition to the above, existing monitoring conducted by MassDEP for eelgrass should continue into the future to observe any changes that may occur to eelgrass populations as a result of restoration efforts.

The MEP will continue working with the Town of Yarmouth to develop and refine monitoring plans that remain consistent with the goals of the TMDL. Through the adaptive management approach ongoing monitoring will be conducted and will indicate if water quality standards are being met. If this does not occur other management activities would have to be identified and considered to reach to goals outlined in this TMDL. It must be recognized however that development and implementation of a monitoring plan will take some time, but it is more important at this point to focus efforts on reducing existing watershed loads to achieve water quality goals.

Reasonable Assurances

MassDEP possesses the statutory and regulatory authority under the water quality standards and/or the State Clean Water Act (CWA) to implement and enforce the provisions of the TMDL through its many permitting programs, including requirements for N loading reductions from on-site subsurface wastewater disposal systems. However, because most non-point source controls are voluntary, reasonable assurance is based on the commitment of the locality involved. Yarmouth has demonstrated this commitment through the comprehensive wastewater planning and efforts to improve flushing in the embayment system through a planned Route 28 culvert widening. The town expects to use the information in this TMDL to generate support from their citizens to take the necessary steps to remedy existing problems related to N loading from on-site subsurface wastewater disposal systems, and stormwater runoff (including fertilizers), and to prevent any future degradation of these valuable resources.

Reasonable assurances that the TMDL will be implemented include enforcement of regulations, availability of financial incentives and local, state and federal programs for pollution control. Stormwater NPDES permit coverage will address discharges from municipally owned stormwater drainage systems. Enforcement of regulations controlling non-point discharges includes local implementation of the Commonwealth's Wetlands Protection Act and Rivers Protection Act and Title 5 regulations for on-site subsurface wastewater disposal systems and other local regulations (such as the Town of Rehoboth's stable regulations). Financial incentives include federal funds available under Sections 319 and 604 programs of the CWA, which are provided as part of the Performance Partnership Agreement between MassDEP and EPA. Other potential funds and assistance are available through Massachusetts' Department of Agriculture's Enhancement Program and the United States Department of Agriculture's Natural Resources Conservation Services. Additional financial incentives include income tax credits for Title 5 upgrades and low interest loans for Title 5 on-site subsurface wastewater disposal system upgrades available through municipalities participating in this portion of the state revolving fund program.

During TMDL implementation by the Town of Yarmouth, the TMDL values (kg/day of N) will be used by MassDEP as guidelines for permitting activities and should be used by local communities as a management tool.

Public Participation
To be completed after public meeting and comments received.

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Appendix A: Summary of the Nitrogen Concentrations for the Parkers River Embayment System

Measured data and modeled nitrogen concentrations for the Parkers River estuarine system used in the model calibration plots. All concentrations are given in mg/L N. The mean nitrogen value represents the mean of separate yearly means. Data represented were collected in the summers of 2002 through 2008.

Sub-Embayment	Station	Mean* (mg/L N)	Standard Deviation	Number Samples	Model Minimum (mg/L N)	Model Maximum (mg/L N)	Model Average (mg/L N)
Seine Pond - Upper	PR-5	0.994	0.229	24	0.953	1.059	1.007
Seine Pond - Lower	PR-1	0.948	0.225	34	0.819	1.046	0.965
Upper Parkers River	PR-2	0.776	0.216	37	0.395	1.022	0.802
Lower Parkers River	PR-3	0.663	0.167	32	0.309	0.76	0.491
Lewis Pond	PR-4	0.868	0.227	36	0.563	1.515	0.859
Nantucket Sound	NTKS	0.294	0.062	4	-	-	-

* mean of separate yearly means

Appendix B: Overview of Applicable Water Quality Standards

Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, bottom pollutants or alterations, aesthetics, excess plant biomass, and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) contain numeric criteria for dissolved oxygen, but have only narrative standards that relate to the other variables. This brief summary does not supersede or replace 314 CMR 4.0 Massachusetts Water Quality Standards, the official and legal standards. A complete version of 314 CMR 4.0 Massachusetts Water Quality Standards is available online at
http://www.mass.gov/eea/agencies/massdep/water/regulations/314-cmr-4-00-mass-surface-water-quality-standards.html

Applicable Narrative Standards

314 CMR 4.05(5)(a) states "Aesthetics – All surface waters shall be free from pollutants in concentrations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances, produce objectionable odor, color, taste, or turbidity, or produce undesirable or nuisance species of aquatic life."

314 CMR 4.05(5)(b) states "Bottom Pollutants or Alterations. All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms."

314 CMR 4.05(5)(c) states, "Nutrients –Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established by the Department pursuant to 314 CMR 4.00. Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication, including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment as determined by the Department, including, where necessary, highest and best practical treatment (HBPT) for POTWs and BAT for non POTWs, to remove such nutrients to ensure protection of existing and designated uses. Human activities that result in the nonpoint source discharge of nutrients to any surface water may be required to be provided with cost effective and reasonable best management practices for nonpoint source control."

Description of Coastal and Marine Classes and Numeric Dissolved Oxygen Standards

Excerpt from 314 CMR 4.05(4) (a):

(a) Class SA. These waters are designated as an excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas). These waters shall have excellent aesthetic value.

1. Dissolved Oxygen. Shall not be less than 6.0 mg/l. Where natural background conditions are lower, DO shall not be less than natural background. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

Excerpt from 314 CMR 4.05(4) (b):

(b) Class SB. These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas). These waters shall have consistently good aesthetic value.

1. Dissolved Oxygen. Shall not be less than 5.0 mg/l. Seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. Where natural background conditions are lower, DO shall not be less than natural background.

Waterbodies Not Specifically Designated in 314 CMR 4.06 or the tables to 314 CMR 4.00
Note many waterbodies do not have a specific water quality designation in 314 CMR 4.06 or the tables to 314 CMR 4.00**.** Coastal and Marine Classes of water are designated as Class SA and presumed High Quality Waters as described in 314 CMR 4.06 (4).

314 CMR 4.06(4):

(4) Other Waters. Unless otherwise designated in 314 CMR 4.06 or unless otherwise listed in the tables to 314 CMR 4.00, other waters are Class B, and presumed High Quality Waters for inland waters and Class SA, and presumed High Quality Waters for coastal and marine waters. Inland fisheries designations and coastal and marine shellfishing designations for unlisted waters shall be made on a case-by-case basis as necessary.

Applicable Antidegradation Provisions
Applicable antidegradation provisions are detailed in 314 CMR 4.04 from which an excerpt is provided:

Excerpt from 314 CMR 4.04:
4.04:Antidegradation Provisions

(1) Protection of Existing Uses. In all cases existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

(2) Protection of High Quality Waters. High Quality waters are waters whose quality exceeds minimum levels necessary to support the national goal uses, low flow waters, and

other waters whose character cannot be adequately described or protected by traditional criteria. These waters shall be protected and maintained for their existing level of quality unless limited degradation by a new or increased discharge is authorized by the Department pursuant to 314 CMR 4.04(5). Limited degradation also may be allowed by the Department where it determines that a new or increased discharge is insignificant because it does not have the potential to impair any existing or designated water use and does not have the potential to cause any significant lowering of water quality.

(3) Protection of Outstanding Resource Waters. Certain waters are designated for protection under this provision in 314 CMR 4.06. These waters include Class A Public Water Supplies (314 CMR 4.06(1)(d)1.) and their tributaries, certain wetlands as specified in 314 CMR 4.06(2) and other waters as determined by the Department based on their outstanding socio-economic, recreational, ecological and/or aesthetic values. The quality of these waters shall be protected and maintained.

(a) Any person having an existing discharge to these waters shall cease said discharge and connect to a Publicly Owned Treatment Works (POTW) unless it is shown by said person that such a connection is not reasonably available or feasible. Existing discharges not connected to a POTW shall be provided with the highest and best practical method of waste treatment determined by the Department as necessary to protect and maintain the outstanding resource water.

(b) A new or increased discharge to an Outstanding Resource Water is prohibited unless:

1. the discharge is determined by the Department to be for the express purpose and intent of maintaining or enhancing the resource for its designated use and an authorization is granted as provided in 314 CMR 4.04(5). The Department's determination to allow a new or increased discharge shall be made in agreement with the federal, state, local or private entity recognized by the Department as having direct control of the water resource or governing water use; or

2. the discharge is dredged or fill material for qualifying activities in limited circumstances, after an alternatives analysis which considers the Outstanding Resource Water designation and further minimization of any adverse impacts. Specifically, a discharge of dredged or fill material is allowed only to the limited extent specified in 314 CMR 9.00 and 314 CMR 4.06(1)(d). The Department retains the authority to deny discharges which meet the criteria of 314 CMR 9.00 but will result in substantial adverse impacts to the physical, chemical, or biological integrity of surface waters of the Commonwealth

(4) Protection of Special Resource Waters. Certain waters of exceptional significance, such as waters in national or state parks and wildlife refuges, may be designated by the Department in 314 CMR 4.06 as Special Resource Waters (SRWs). The quality of these waters shall be maintained and protected so that no new or increased discharge and no new or increased discharge to a tributary to a SRW that would result in lower water quality in the SRW may be allowed, except where:

(a) the discharge results in temporary and short term changes in the quality of the SRW, provided that the discharge does not permanently lower water quality or result in water quality lower than necessary to protect uses; and

(b) an authorization is granted pursuant to 314 CMR 4.04(5).

(5) Authorizations.

(a) An authorization to discharge to waters designated for protection under 314 CMR 4.04(2) may be issued by the Department where the applicant demonstrates that:

1. The discharge is necessary to accommodate important economic or social development in the area in which the waters are located;

2. No less environmentally damaging alternative site for the activity, receptor for the disposal, or method of elimination of the discharge is reasonably available or feasible;

3. To the maximum extent feasible, the discharge and activity are designed and conducted to minimize adverse impacts on water quality, including implementation of source reduction practices; and

4. The discharge will not impair existing water uses and will not result in a level of water quality less than that specified for the Class.

(b) An authorization to discharge to the narrow extent allowed in 314 CMR 4.04(3) or 314 CMR 4.04(4) may be granted by the Department where the applicant demonstrates compliance with 314 CMR 4.04(5)(a)2. through 314 CMR 4.04(5)(a)4.

(c) Where an authorization is at issue, the Department shall circulate a public notice in accordance with 314 CMR 2.06. Said notice shall state an authorization is under consideration by the Department, and indicate the Department's tentative determination. The applicant shall have the burden of justifying the authorization. Any authorization granted pursuant to 314 CMR 4.04 shall not extend beyond the expiration date of the permit.

(d) A discharge exempted from the permit requirement by 314 CMR 3.05(4) (discharge necessary to abate an imminent hazard) may be exempted from 314 CMR 4.04(5) by decision of the Department.

(e) A new or increased discharge specifically required as part of an enforcement order issued by the Department in order to improve existing water quality or prevent existing water quality from deteriorating may be exempted from 314 CMR 4.04(5) by decision of the Department.

(6) The Department applies its Antidegradation Implementation Procedures to point source discharges subject to 314 CMR 4.00.

(7) Discharge Criteria. In addition to the other provisions of 314 CMR 4.00, any authorized Discharge shall be provided with a level of treatment equal to or exceeding the requirements of the Massachusetts Surface Water Discharge Permit Program (314 CMR 3.00). Before authorizing a discharge, all appropriate public participation and intergovernmental coordination shall be conducted in accordance with Permit Procedures (314 CMR 2.00).

Appendix C: Estimation of N Wasteload Allocation for Impervious Area sources

Table C1: Parkers River Embayment System- Estimation of N Loading Contribution from 200 foot buffer to estuarine waterbodies

Parkers River System Waterbody Subembayment Watershed	Subwatershed Impervious Area in 200ft Buffer of Embayment Waterbody (acres)[1]	Total Subwatershed Impervious Area (acres)	Subwatershed Impervious Area in 200ft buffer as Percentage of Total Subwatershed Impervious Area	MEP Total Unattenuated Subwatershed Impervious Load N (kg/day)	MEP Total Unattenuated Subwatershed Load (kg/day)[2]	Subwatershed Impervious buffer (200ft) WLA (kg/d)[3]	Subwatershed buffer area WLA as percentage of MEP Total Unattenuated Subwatershed Load[4]
Seine Pond	3.69	336.33	1.10%	1.92	25.05	0.02	0.08%
Upper Parkers River	0.81	99.49	0.81%	1.42	20.56	0.01	0.06%
Lower Parkers River	18.38	52.99	34.69%	0.49	12.65	0.17	1.34%
Lewis Pond	1.27	113.70	1.12%	1.33	17.53	0.01	0.08%
Total	24.15	602.51	4.01%	5.15	75.78	0.22	0.29%

1 The entire impervious area within a 200 foot buffer zone around all waterbodies as calculated from GIS.

2 This includes the unattenuated nitrogen loads from wastewater from septic systems, fertilizer, runoff from both natural and impervious surfaces, atmospheric deposition to freshwater waterbodies and wastewater from one wastewater treatment facility. This does not include direct atmospheric deposition to estuary surface.

3 The impervious subwatershed buffer area (acres) divided by total subwatershed impervious area (acres) then multiplied by total impervious subwatershed load (kg/year).

4 The impervious subwatershed buffer area WLA (kg/yr) divided by the total subwatershed load (kg/yr) then multiplied by 100.

MassGIS (2014). *Impervious Surface Polygons (from 2005 Imagery) Data Layer*. Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, Information Technology Division, Boston, MA.

Appendix D: Summary of TMDLs Developed

Table D1: Summary of TMDLs Developed as part of MEP project for Parkers River Embayment System – 3 Total Nitrogen TMDLs

Parkers River Embayment System Waterbody Name	Description	MassDEP Segment Number (if applicable)	TMDL (kg/day)
Seine Pond	Restoration TMDL, determined to be impaired for nutrients during the development of this TMDL.	MA96-110_2018	**5.18**
Upper Parkers River			4.90
Lower Parkers River			18.02
Parkers River	Restoration TMDL, determined to be impaired for nutrients during the development of this TMDL. Final TMDL previously issued for pathogens.	MA96-38	**22.92**
Lewis Pond	Restoration TMDL, determined to be impaired for nutrients during the development of this TMDL.	MA96-109_2018	**7.37**
Parkers River System		**Total**	**35.47**